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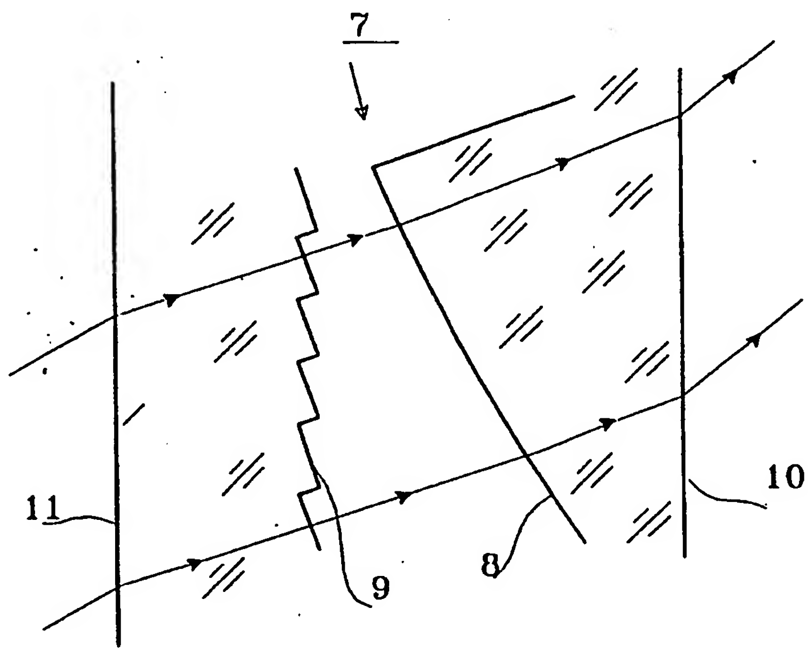
(54) Title: ILLUMINATION DEVICE FOR A PROJECTOR

(57) Abstract

An illuminating arrangement for overhead and video projection which with the aid of a combination of refractive (8) and diffractive (9) optical elements makes possible color-corrected focussing of illuminating light into a projection objective, which may be displaced laterally.



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ILLUMINATION DEVICE FOR A PROJECTOR.

According to a primary aspect, the invention relates to an illumination arrangement for a projection system of the kind that can be exemplified, for instance, by an overhead projector but which can also be used for other purposes in which a transmitted picture or image is to be projected. A known illumination arrangement includes in the close vicinity of the image to be projected an optical plate which is illuminated from beneath and which is divided into light-refractive zones, in a simplest case a Fresnel lens. Such a plate exhibits pronounced colour errors, due to the dispersion of the material, i.e. the different sized refractive indexes for different colours.

Consequently, present-day illumination arrangements used with present-day overhead apparatus leave much to be desired. Light from the light source is caused to pass through the transmitted image as convergent light rays directed towards the objective. Unfortunately, the deficient colour correction of the illumination system causes the projected image to lose in contrast. Furthermore, much stray light is obtained.

According to one aspect of the invention, the aim is to provide an illumination arrangement which will provide improved illumination in the aforesaid respect.

According to one particular aspect of the invention, it is desired to provide an improved illumination arrangement for a projector wherein the projection objective is displaced or offset in relation to a normal through the centre point of the transmission image. One such projector in the form of an overhead projector is known from SE-B-457,022. The apex of the light cone arriving from the transmission image lies within the projection objective. A projection arrangement of this kind used with an overhead projector affords

better ergonomy since it allows the projector to be placed on one side of the projected image without the image being obscured by the projector or its operator.

Another object is to provide an illumination apparatus of the aforesaid kind which is light in weight and of small bulk.

According to one aspect of the invention, diffractive elements having transmissive profile structures are disposed in the various zones of the flat optical plate.

The fundamental problem of colour error is solved in accordance with one aspect of the invention, by combining an optical, refractive, zone-divided plate with diffractive elements. A diffractive element, which can be seen as a grating or a periodic structure, is able to bend light to different extents depending on wavelength, and can be given an appropriate dispersion. By suitable configuration of the periodic structure, it is possible, analogously with grating with blaze, to cause a predominant part of the light delivered to pass through in a desired direction. In this regard, there are preferably used computer-generated phase holograms, either a relief hologram or volume hologram, and it is actually possible to achieve an almost 100% efficiency. The diffractive element may advantageously be embossed in a transparent thermoplastic material, for instance PMMA, with a master which is produced in a known way, for instance by electron beam lithography or laser scanner lithography.

The thus combined optically acting plate is normally mounted in the direction of propagation of the light as seen in front of the transmission image. However, there is nothing to prevent the optically active elements from being mounted either completely or partially on the opposite side of the image. It may be suitable to arrange parts of the

optically active elements on opposite sides of the transmission image, particularly when the transmission image is an LCD unit whose different pixel units are controlled by video signals. The different elements can then be perceived as being a composite light directing element for each pixel which projects light, possibly modified by the pixel, towards a projection objective.

One aspect of the invention can be applied with overhead projectors having an illumination arrangement which includes a Fresnel lens, which can be achromatized by the invention.

One aspect of the invention can also be applied with projectors in which the projected image derives from an LCD device, which may be controlled by video signals. In this regard, for projecting colour images or pictures in one embodiment it is possible to operate with one single LCD device in a time multiplex system in which light of several colours is projected one colour at a time with the LCD device successively set for colour-separated fields. In another embodiment, separate fields are projected simultaneously from a respective LCD device and combined, for instance, with the aid of dichroic mirrors, to achieve projection with a common projection objective. In a third embodiment, separate fields are projected for different colours, by colour separation in one and the same LCD device. In a fourth embodiment, there is a used a combination of the first and the third embodiments, wherein one and the same light valve in the LCD device can be used for time-multiplexed colours that lie close together in the spectrum.

Although one aspect of the invention can be applied in the case of conventional projection with the images arranged symmetrically in relation to the optical axis of the objective, this will often result in ergonomical problems,

as made apparent in US-A-4,988,176, for instance, in which it is proposed to displace the image, or picture, so as to enable the projector to be placed on one side of a projection screen. In order to obtain an illumination arrangement which is adapted to this type of projection, the arrangement must be able to produce a light cone which exits from the image towards the object with, so to speak, an oblique base represented by the image.

According to a first embodiment, the illumination arrangement may include a plate having an asymmetrical, but otherwise relatively normal Fresnel lens, where the different rings of circles are combined with diffractive surface structures. According to a second embodiment, it is suitable to arrange the refractive effects through microlenses or microprisms that are adapted pixel-wise and each of which is achromatized by means of diffractive structures, this being particularly so in LCD applications.

The plate may be illuminated directly or via other elements, for instance via an elliptical or parabolic mirror, which has the advantage that no colour errors will be introduced. The plate may also be illuminated with the aid of a Fresnel lens located adjacent the plate, wherein the colour errors occurring in said Fresnel lens can be corrected with the aid of the diffractive element in the plate.

One aspect of the invention enables the projection to be displaced laterally and in a height direction, by allowing a large refractive force of the illumination object without colour error, which is highly significant when designing the projection objective, which can hereby be given a smaller diameter and a fewer number of lens elements. The further object of the invention can be achieved to a particularly high degree when using a novel type of optical element which is able to produce a uniformly distributed,

collimated broadened beam path in a direction orthogonal to the direction of the incoming light. Such a component can be produced with the aid of a series of planar surfaces which are positioned obliquely to the incoming beam path and which are partially reflecting and transmitting over the whole of the visible spectrum.

Different aspects of the invention will now be described with reference to exemplifying embodiments thereof.

Fig. 1 illustrates very schematically an example of an illumination arrangement together with a light source and a projection system. Fig. 2 is a sectional view of a small part of a Fresnel lens coacting with a diffractive structure. Fig. 3 illustrates a highly schematic example of a compact overhead projector with which imaging is displaced both laterally and in a height direction. Fig. 4 illustrates the groove structure in Fresnel lenses and gratings for the light-directing, colour-corrected plate in the projector shown in Fig. 3. Fig. 5 illustrates the principle of producing a component that is capable of producing a uniformly distributed, collimated broadened beam path in a direction orthogonal to the direction of the incoming light. Fig. 6 illustrates the construction of the optic which directs light in towards the projection objective. Figs. 7 and 8 illustrate two embodiments with colour separation in an LCD projector.

Fig. 1 illustrates an inventive illumination arrangement having an image carrier 1, which may be a large diapositive or an LCD device. The Figure illustrates solely an example of the field of use of the invention, in this case in conjunction with an overhead projector. A carrier plate 4 which includes a Fresnel lens and a diffraction element is illuminated by a light beam generated by a light source 2 and a mirror 3. The Fresnel lens and diffraction element cause the light beam passing through the image carrier to

converge in the schematically illustrated objective 5, which images the image in the image carrier 1 on a screen 6 in a greatly enlarged view. In this example, the beam path in the objective is oblique, which enables the image on the screen 6 to be displaced laterally. It will be understood that in the case of an overhead projector, there is provided a reflective surface (not shown) and that the beam path enables the entire projection arrangement to be placed on one side of the screen 6.

A characteristic feature of one aspect of the invention is that the optically active carrier plate 4 is achromatized by a combination of refractive and diffractive elements. This achromatization may also include a correction of the colour errors in an adjacent Fresnel lens. Fig. 2 is an illustrative example in the form of a radial section through a ring part 7 of a Fresnel lens. With incident monochromatic light, the light will be refracted as it passes through the surface 8 in the same way as in a corresponding lens. However, since refractive index varies with wavelength, a colour error will occur, since longwave light is refracted to a lesser extent than shortwave light. In accordance with one aspect of the principle of the invention, however, the planar surface 9, which is provided with a dispersive surface on the opposite side, can be seen as a bending grating. Gratings have the property whereby their bending is greater for longwave light than for shortwave light. Consequently, by selecting an appropriate grating constant, the difference in bending for different colours in the grating surface 9 will be able to compensate for the difference in refraction in the surfaces 8, 10 and 11 - we assume that the surface 9 is throughpassed at right angles.

The dispersion compensation for the colour error in the refraction is due to the variation in refractive index and also due to the refractive angle according to Snell's law.

It is therewith necessary to determine the grating constant for the surface 9 so as to obtain compensation for bending of the first order. The so-called blaze angle is set so as to obtain the greatest possible intensity in the first order, which theoretically may be 100% of the incident light for one single wavelength. One optimizes for one wavelength in green colour, which results in moderate losses in both red and blue, particularly in view of the fact that the eye is less sensitive in these latter ranges.

It is possible to assume that the refractive angle for each ring or circle in a Fresnel lens is equally as large. The grating constant may also be allowed to vary continuously. Manufacture is suitably effected holographically or with so-called computer holography, which also enables highly complicated forms to be obtained. It should be mentioned that in the case of a construction as in the plate 4 in which the Fresnel lens used is preferably decentered, the grating constant will vary along each individual band of the lens.

The configuration shown in Fig. 2 which hitherto has been taken to symbolize a radial cross-section through a ring in a Fresnel lens may also be seen as imaging a section through a general microlens or a microprism. In the case of an LCD application, it is suitable to provide one such microelement for each pixel area. Because of the resultant achromatization, it is then possible to illuminate the LCD unit successively with successively different colours while successively showing fields.

Fig. 5 illustrates the principle of producing a component 12 which is capable of providing a uniformly distributed, collimated broadened beam path in a direction orthogonal to the direction of the incoming light. The light from the light source 2 is collimated with the aid of the optic 14, whereafter parts of the light are reflected successively in

a generally orthogonal direction to the originals, so as to obtain a broad and uniform light distribution 20 out from the arrangement.

Fig. 3 is a highly schematic exemplifying illustration of a compact overhead projector with which imaging is displaced both laterally and in a height direction. A beam of collimated light is sent into the device 13 via the unit 12, said device being constructed with obliquely positioned, partially reflecting and partially transmitting mirrors analogously to the device 12, so that the light will be collimated and directed towards the transparent image 1. Located between the device 13 and the transparent image 1 is a light-directing, colour-corrected plate which directs the light up to and into the objective 5. The light is then deflected with the aid of a three-edge prism, where total reflection is possibly utilized. A switch can be made between right-side and left-side projection, by rotating the deflecting unit 14 about a vertical axis while simultaneously rotating the projector through 90 degrees in an opposite direction, as described in Swedish Patent Application No. 9300959-5. The projection objective may also advantageously be positioned so that its orthogonal projection to the plane of the transparent image (1) will lie outside one corner of the transparent image, thereby obtaining further lateral displacement of the image. When the transparent image is a fixedly mounted rectangular electronically generated transparent image, for instance in an LCD, it is possible to switch between a left-hand displaced and right-hand displaced image projected on the screen 11, by rotating the deflecting unit through 180 degrees while simultaneously rotating the whole of the projector through 180 degrees in the horizontal plane and electronically turning the image upside down.

Fig. 4 illustrates schematically the groove structure of Fresnel lenses and gratings for the light-directing,

colour-corrected plate in the projector shown in Fig. 3. The reference numeral 19 identifies the corner that lies nearest the projection objective. When the projection objective is so positioned that its orthogonal projection to the plane of the transparent image 1 will lie outside one corner of the transparent image, the centre of the grooves will be displaced correspondingly to lie outside the transparent image. In a similar manner, the rotational centre is displaced inwardly towards the centre of the transparent image when the projection objective is displaced inwardly towards the centre of the transparent image.

Fig. 6 is a highly schematic side projection of the construction of the optic which directs the light in towards the projection objective. The collimated light 19 arriving from the device 13 first passes a positive Fresnel lens 18 and then a diffractive element 17, which may be a blazed grating having a varying grating constant and blaze angle. The light then passes through a second Fresnel lens 16. The diffractive element is formed so that the colour errors occurring in the two Fresnel lenses will be compensated for. Naturally, it is possible to use only one Fresnel lens instead of two.

Fig. 7 illustrates very schematically an LCD projector which operates with colour separation technique, i.e. the different colours R, G and B are separated within dedicated light valves 1R, 1G and 1B. The light arrives in mutually different directions 311 and 312 at a microlens matrix 322 having positive microlenses 94. Light in the three different colours impinges on its respective negative microlens 314R, 314G and 314B in a second microlens matrix 323 and then passes to its respective light valve 1R, 1G and 1B in an LCD matrix 1, whereafter they reach the light-directing, colour-corrected combinations 7R, 7G and 7B of diffractive matrix elements and microprisms in the matrices 21 and 22.

Fig. 8 illustrates highly schematically an LCD projector operating with colour separation technique, i.e. the different colours R, G and B are separated within dedicated light valves 21R, 1G and 1B. Light arrives at a microlens matrix 322 having positive microlenses 94 in the mutually different directions 311 and 312. Light in the three different colours impinges on a respective light valve 1R, 1G and 1B in an LCD matrix 1, whereafter they reach the light-directing, colour-corrected combinations 7R, 7G and 7B of diffractive matrix elements and microprisms in the matrices 21 and 22.

In the arrangement illustrated in Fig. 5, the reflectance r_i of the i:th mirror in the light direction should generally be:

$$r_i = 1/(n-i+1/r_n) \qquad i = 1..n \qquad (1)$$

where n is the total number of mirrors.

The n:th mirror is purely reflective and has the reflection factor r_n. The formula (1) can be modified with regard to losses in the individual mirrors. A simple representation of the reflectance r_i for the i:th mirror when the mirrors have losses is given in the formula (2) below.

$$r_i = 1/(\sum_{j=1}^{?}(+w_j) - \sum_{j=1}^{i-1}(1+w_j)) \qquad i = 1..n \qquad (2)$$

where the loss in the i:th mirror is defined so that it is w_j*J, where J is that part of the light which is reflected by each mirror.

CLAIMS

1. An illumination arrangement for illuminating a transparent image (1) from one side thereof and for producing a through-passing convergent or collimated light beam for projection of the image by means of a projection optic (5) which can be placed in a convergence point, wherein the illumination arrangement includes at least one light source (2) and a flat optical plate (4) which can be placed close to the transparent image, wherein the flat optical plate is divided into different zones (7) which influence the directions of light beams that are caused to pass through, and wherein optically refractive elements (8) are included, **characterized** in that the different zones include transmissive diffractive elements (9) having profile structures or volume structures; in that the diffractive elements exhibit dispersions which for visible light have opposite signs and values which are substantially equally as large in relation to the dispersions of the earlier optically refractive elements, so as to achieve achromatic compensation for the illumination arrangement within said zones.

2. A collimator for collimating spectrally both broadband and narrow band light, **characterized** in that light from the light source (2) first passes a light distributing device (12) having partially reflecting and partially transmitting mirrors (15) which are inclined at an angle of 45 degrees to the light direction and which provide uniform light distribution in a direction orthogonal to the earlier direction.

3. A collimator according to Claim 2, **characterized** in that the light from the light source (2) first passes a light-distributing device (12) having partially reflecting and partially transmitting mirrors (15) which are inclined at angles of 45 degrees to the light direction and which

provide uniform light distribution in a direction orthogonal to the earlier light direction, and then passes a second light distributing device (13) having partially reflecting and partially transmitting mirrors which are inclined at an angle of 45 degrees to said light direction, said mirrors providing uniform light distribution in a direction orthogonal to both of the earlier light directions.

4. A collimator according to one of Claims 2-3, **characterized** in that the reflectance r_i i:th mirror in a row of uniformly inclined mirrors is given essentially by

$$r_i = 1/(n-i+1/r_n) \qquad i = 1..n \qquad (1)$$

where n is the total number of mirrors.

5. An illumination arrangement according to Claim 1 and one of Claims 2-4, **characterized** in that the collimator (12, 13) is used for illuminating the transparent image (1) and the optical plate (4).

6. An illumination arrangement according to Claim 5, **characterized** in that the optical plate (4) is comprised of a number of positive Fresnel lenses (16, 18) and a diffractive element (17).

7. An illumination arrangement according to Claim 6, **characterized** in that the optical plate (4) is comprised of two positive Fresnel lenses (16, 18) with intermediate diffractive element (17).

8. An illumination arrangement according to one of Claims 1 or 5-7, **characterized** in that the optical plate (4) has a rotational centre which coincides generally with one of the corner points (19) of the plate or with a point outside one of the corner points of said plate.

9. A projection arrangement according to one of Claims 1 or 5-9, **characterized** in that a light deflecting device (14) is able to pivot up to at least 90 degrees, wherewith the image can be projected, with the image (1) orientated horizontally, onto a vertical wall or corresponding structure, or alternatively in two different directions.

10. A projection arrangement according to one of Claims 1 or 5-9, **characterized** in that a light-deflecting device (14) can pivot up to an angle of at least 180 degrees, wherewith the image can be projected, with the image (1) orientated horizontally, onto a vertical wall or corresponding structure, or alternatively in two different directions.

11. An illumination arrangement according to one of Claims 1 or 5-10, **characterized** in that the diffractive elements (9) in the optical plate (4) have the form of computer-generated phase holograms.

12. An illumination arrangement according to one of Claims 1 or 5-10, **characterized** in that the diffractive elements (9) in the optical plate (4) are blazed.

13. An illumination arrangement according to one of Claims 1 or 5-12, **characterized** in that the diffractive elements in the optical plate include a master-embossed surface in a coating of transparent thermoplastic material.

14. A projection arrangement according to one of Claims 1 or 11-13, **characterized** in that on the entrance to the image transmission element (1) having the light valves (1R, 1G, 1B) there has been collimated or converged light of different colours and mutually different directions (311, 312), which first meets a matrix (322) having colour-separating positive microlenses (94) followed by a matrix (323) of negative microlenses (314R, 314G, 314B); and in

that the optical plate (4) containing matrices having the colour-corrected, light-directing elements (7R, 7G, 7B) is on the exit side of the image transmission element (1).

15. A projection arrangement according to one of Claims 1 or 11-14, **characterized** in that collimated or convergent light of different colours and mutually different directions (311, 312) is present on the entrance to the image transmission elements (1) having the light valves (1R, 1G, 1B), wherein said light first meets a matrix (322) having colour-separating positive microlenses (94); and in that the optical plate (4) containing matrices having the colour-corrected, light-directing elements (7R, 7G, 7B) is on the exit side of the image transmission element (1).

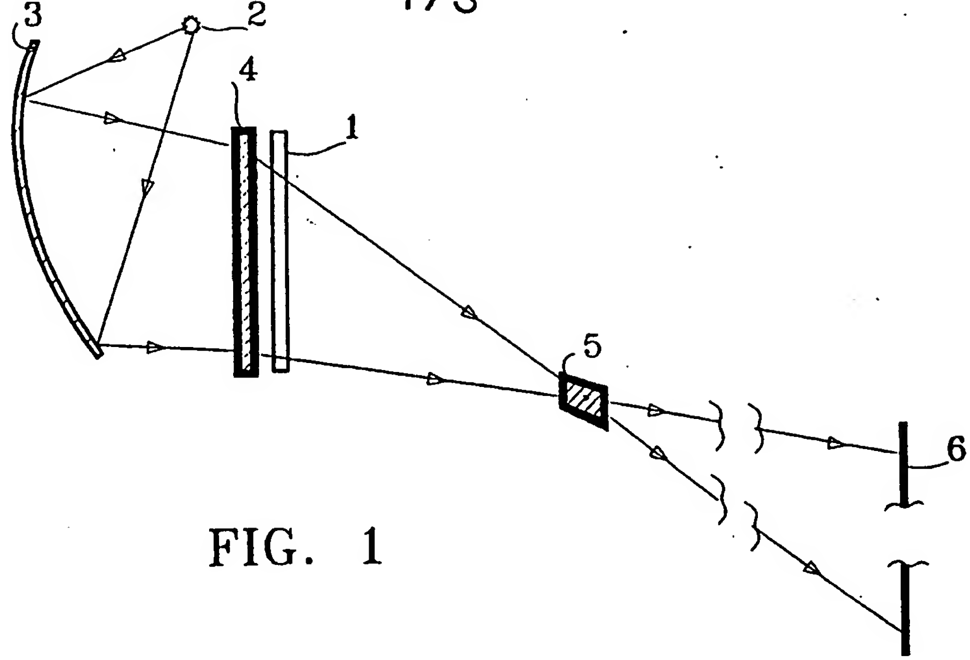

FIG. 1

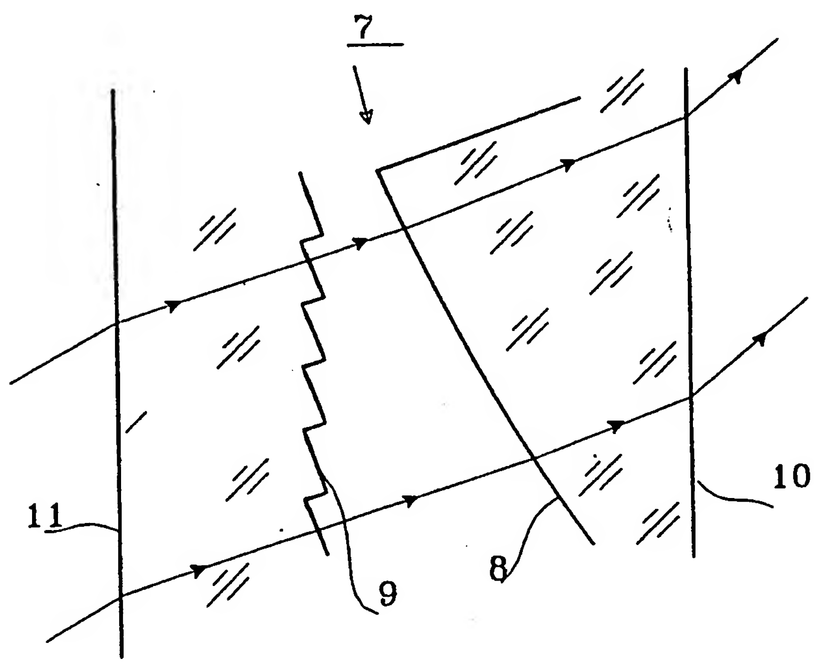

FIG. 2

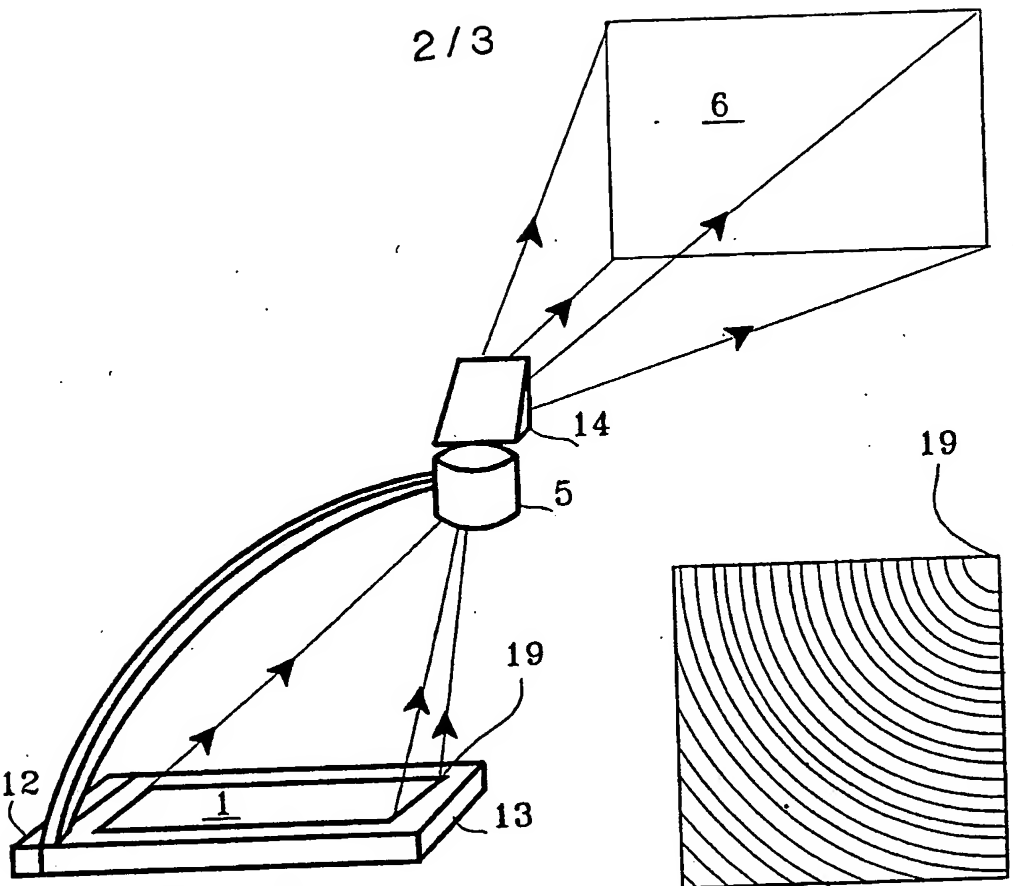

FIG. 3

FIG. 4

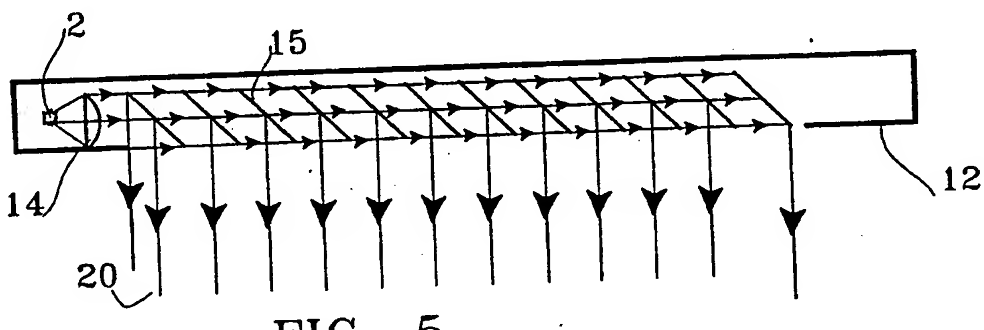

FIG. 5

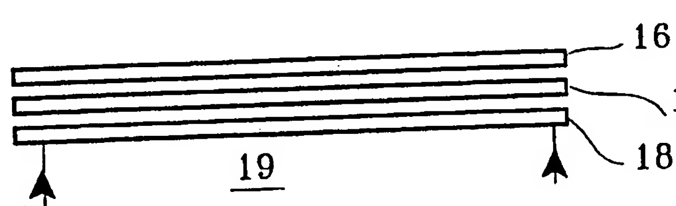

FIG. 6

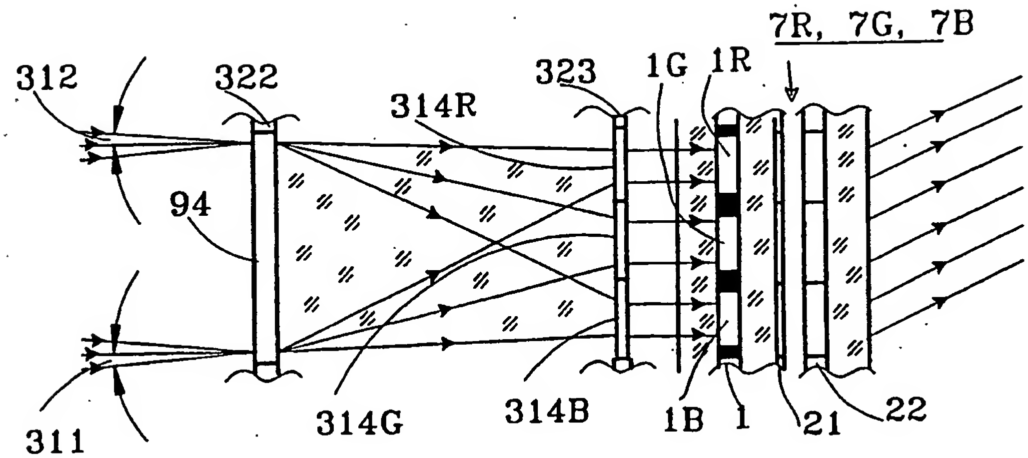
7R, 7G, 7B
312
322
323
1G
1R
314R
94
314G
314B
1B
1
21
22
311

FIG. 7

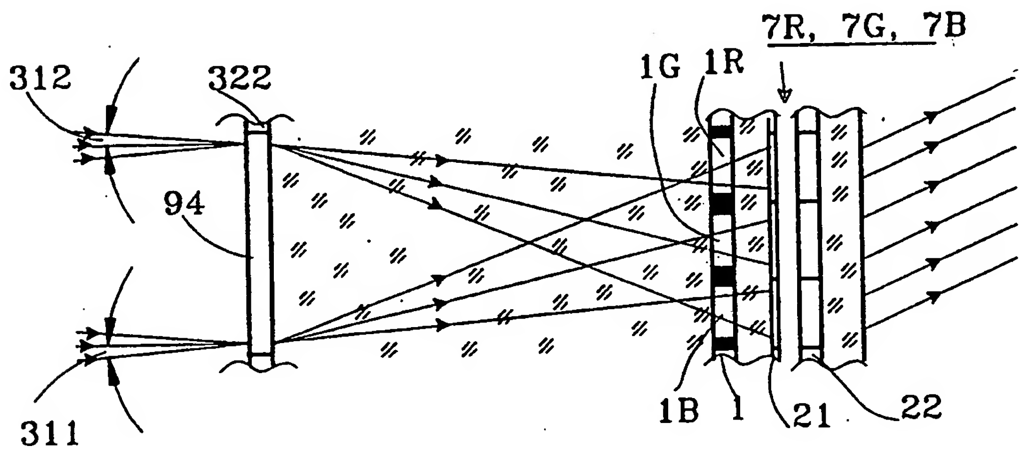
7R, 7G, 7B
312
322
1G
1R
94
1B
1
21
22
311

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 94/00254

A. CLASSIFICATION OF SUBJECT MATTER

IPC 5 : G03B 21/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 5 : G03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CLAIMS, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP, A1, 0115901 (MINNESOTA MINING AND MANUFACTURING COMPANY), 15 August 1984 (15.08.84) --	1-15
A	EP, A2, 0359494 (MINNESOTAMINING AND MANUFACTURING COMPANY), 21 March 1990 (21.03.90) --	1-15
A,P	US, A, 5296882 (NELSON ET AL), 22 March 1994 (22.03.94) -- --------	1-15

[ ] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
23 June 1994	08 -07- 1994
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Björn Kallstenius Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

28/05/94

International application No.
PCT/SE 94/00254

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A1- 0115901	15/08/84	CA-A- 1240542	16/08/88
		DE-A- 3467428	17/12/87
		JP-A- 59136726	06/08/84
		US-A- 4436393	13/03/84
EP-A2- 0359494	21/03/90	CA-A- 1327468	08/03/94
		JP-A- 2120785	08/05/90
		US-A- 4943156	24/07/90
US-A- 5296882	22/03/94	NONE	

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 02/02616

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N9/31

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP 0 425 266 A (MATSUSHITA ELECTRIC IND CO LTD) 2 May 1991 (1991-05-02) column 3, line 2-29; figure 1C	1-5,7,8, 23,28 9,19,20, 29
X Y	US 5 508 834 A (YAMADA NAOKI ET AL) 16 April 1996 (1996-04-16) column 4, line 57 -column 5, line 2; figure 7	1-5,7,8, 23,28 9,19,20, 29
X Y	US 5 398 125 A (WILLETT STEPHEN J ET AL) 14 March 1995 (1995-03-14) column 2, line 15-47; figure 1 column 1, line 14-26	1-5,7,8, 22,23,28 9,19,20, 29

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 September 2002	24/09/2002

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 010, no. 143 (P-459), 27 May 1986 (1986-05-27) & JP 60 262131 A (SHARP KK), 25 December 1985 (1985-12-25)	1-5,7,8, 23,28
Y	abstract	9,19,20, 29
Y	US 6 122 023 A (JACHIMOWICZ KAREN E ET AL) 19 September 2000 (2000-09-19) column 1, line 32-37	9,29
Y	US 5 136 390 A (DEL CASTILLO LEONARDO ET AL) 4 August 1992 (1992-08-04) column 2, line 53 -column 3, line 7	19,20
A	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 02, 29 February 2000 (2000-02-29) & JP 11 313346 A (SHARP CORP), 9 November 1999 (1999-11-09) abstract	9,30,31